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Full Length Research

Geotechnical Assessment of Amuzukwu-Ibeku Lateritic Soil and Its Implication for Use as Subgrade Material

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There is increasing need for the use of local materials in major constructions in countries lying within the tropical regions of the world. Geotechnical properties of soils used for these constructions should be carefully and comprehensively studied to avoid inappropriate designs, delays in construction schedules, expensive construction modifications, use of substandard burrow material, post construction remedial work, failure of a structure and subsequent litigation, as the case may be. However, Amuzukwu-Ibeku lateritic soil has been used on several occasions as a subgrade material in road constructions within the Umuahia region of Abia State. Thus, this paper investigated the geotechnical properties of this soil, which led to the observation of its substandard nature. All analyses were carried out in accordance to the British Standard Institution. The liquid limit of the soil has an average of 52%, plastic limit of 34% average and plasticity index of 18%. The maximum dry density of the soil is 2.01g/cm^3 while the optimum moisture content is 8.88% with a CBR of 8%. According to AASHTO classification of soils, Amuzukwu-Ibeku lateritic soil belongs to A-7-5 subgroup, having a Plasticity Index less than the LL – 30 and has a general rating of "fair to poor" as a subgrade material. From the results, the soil is unsuitable for use as subgrade material, and this attributed to countless road failures experienced in regions where this soil was used as a construction material.

Keywords: Geotechnical Assessment; Lateritic Soil; Amuzukwu-Ibeku; Soil Properties; Subgrade; Stabilization.

INTRODUCTION

All soils are formed of materials which have undergone a complex chemical and physical weathering process. This weathering process is complex because it takes millions of years and during the process, the principal agents which affect soil development e.g., physiography, geology and climate, also undergo changes. Laterite is a highly weathered material, rich in secondary oxides of iron,

aluminum or both. It is void or nearly void of basic primary silicates, but it may contain large a mounts of quartz and kaolinite (Alexandra and Cady, 1962). It is very important to understand the detailed properties of lateritic soils when they are going to be a commercial product for industrial application. During feasibility studies on the assessment of Amuzukwu-Ibeku lateritic soil, the data from the report indicated that the top part (laterite) contains more fines (silt/clay) than the bottom stratum. It is apparent that the entire sequence is sandy, with a small percentage of silt/clay. From the report it was established that the moderate density values from the feasibility showed that the soil is loose; a condition that favours easy soil dispersal and lateritic (Egboka and Okpoko, 1984). This makes the soil easily erodible, a point that is buttressed by the high void ratios porosities. The mineralogical composition of the soils has an influence on the geotechnical parameters such as specific gravity, shear strength, swelling potential, Atterberg limits, bearing capacity and petrographic properties (Amadi et al., 2012).

In Nigeria, the non-availability of generalized relevant data in this area, particularly for initial preliminary engineering planning and designs, has been the bane and cause of failure of most of our highway construction projects, such that, failure occurs almost immediately after the project is commissioned or even before. The construction material which is used for engineering highway projects is therefore as important, as other engineering design factors. In this tropical part of the world, lateritic soils are used as a road making material and they form the sub-grade of most tropical road.

OVERVIEW OF AMUZUKWU-IBEKU COMMUNITY

Amuzukwu-Ibeku is a community located in Umuahia North LGA, of Abia State. It is geographically located within the coordinates N 05^o 32' and N 05^o 41'Latitude and E007^o 28' and E007^o 32' Longitude. This region has a tropical climate. The average annual temperature in Amuzukwu is 26.3°C, about 2137mm of precipitation falls annually. The difference in precipitation between the driest month and the wettest month is 305mm. The average temperatures vary during the year by 2.9°C (NEWMAP, 2015). The area experiences a high rainfall with corresponding high discharge of water as runoff, which encourages lateritic. It has a peak period between July and September. In a study conducted by (Jimoh, 2005), rainfall events were found to be highly correlated to lateritic in the entire representative land surface types.

MATERIALS AND METHODS

Sampling

Soil samples were collected in-situ from the Lateritic site at Amuzukwu-Ibeku Community. The soil samples were collected and packaged in polythene bags for laboratory analysis. These analysis/tests were carried out at Niger Pet Geotechnical Laboratory.

Laboratory tests

Particle Size Analysis

This was done by carrying out the gradation exercise on the soil sample and determining all the characterization properties that enabled proper classification of the studied soil.
The grain size analysis test results for the soil sample under investigation at different testing conditions were summarized. The values which were obtained from the gradation tests were analyzed with respect to the effect of pre-treatment and soil variations along lateral and depth wise. From the weight of particles retained, percentage retained and percentage passing was deduced.

Atterberg Limit

This was achieved by using Cassangrende apparatus available in Niger-Pet Soil Mechanical Laboratory to determine the consistency properties, i.e., liquid limit, plastic limit and plasticity index of the studied soil. This aids in determining the plastic nature of the soil thereby proposing ways of arresting plasticity problems if there are any. The results which were obtained for the Atterberg Limit tests were tabulated.

Specific Gravity

Specific gravity of the soil samples under investigation was determined using AASHTO T100 03, T85-91 procedures. It was used to calculate

Table 1. Properties of Amuzukwu-Ibeku Lateritic Soil from the Laboratory Test Results.

PROPERTIES	RESULT
% passing BS sieve no 200	48.18
L.L (%) P.L (%)	52 34
P.I (%)	18
AASHTO Classification	A-7
USCS Classification	G P
MDD (g/cm^3)	2.01
OMC (%)	8.88
UCS (KN/m^2)	311.07
CBR (%)	8
SPECIFIC GRAVITY	2.27
Ultimate Bearing Capacity (kn/m^2)	434.252
Colour	Reddish

parameters such as void ratio, porosity, soil particle size distribution by means of the hydrometer, degree of saturation, etc. The specific gravity tests of the soil was carried out and summarized.

Compaction Test

Compaction Test was carried out and tabulated to determine the compaction properties i.e., Maximum Dry Density and Optimum Moisture Content of the studied soil and to establish how these properties contribute to the defects of this soil in respect to construction activities.

Strength Test (California Bearing Ratio and Unconfined Compression)

This involved determining the shearing resistance of the studied soil sample in order to analyze soil stability problems, such as bearing capacity, slope stability, and lateral pressure on earth-retaining structures.

Triaxal Test

This was done to determine the shear strength of the soil in respect to withstanding horizontal and vertical loads. Normal stresses were employed in all the direct shear tests and the result was presented in the form of stress-strain curves and plots of shear stress versus normal stress. From these, the shear strength parameters (angle of cohesion (c) and angle of internal friction (Φ) were obtained.

RESULTS AND DISCUSSION

In the particle size result from Table 2, it is observed that the % passing through sieve no. 200 is 48.18 and thus, has a Zero Coefficient of Curvature and Uniformity, thus, the soil is Poorly Graded. However, when poorly graded soil formations are subjected to the actions of erosion via precipitation, surface runoff occurs and if this steady runoff which is proportional to the amount of precipitation is not checked, sheet erosion occurs gradually and overtime, the formation of gullies will take place.

Atterberg limit test is an important soil test in environment and foundation studies. It gives an indication of the consistency limits of the soil. Thus, from Table 3 and Figure 2, this soil is classified under group A-7 soils, according to the AASHTO system of soil classification and is generally rated as fair to poor. The liquid limit, plastic limit and plasticity index of the soil are 52%, 34% and 18% respectively. According to the Federal Ministry of Works and Housing, the Liquid Limits and Plasticity Index of subgrade should be ≤30% and ≤10% respectively. Thus from this result, the soil is unsuitable for use as subgrade.

From Table 4, the compaction result shows that the maximum dry density (MDD) has a mean value

Table 2. Result of Sieve Analysis Test of the Soil Sample

PROJECT/LOCATION: AMUZUKWU LATERITIC SITE						
SAMPLE REF:			Weight of Wet Sample:	200.00grms	Weight of Dry Sample:	105.48 grms
SIEVES		Weight Retained	Percentage Retained	Percentage Cummulative	Percentage Passing	Specification
3 Inches	75 mm	-	-	-	100.00	
2 1/2 Inches	63 mm	-	-	-	100.00	
1 1/2 Inches	37.50 mm	-	-	-	100.00	
1 Inches	26.50 mm	-	-	-	100.00	
3/4 Inches	19 mm	-	-	-	100.00	
1/2 Inches	13.20 mm		-	-	100.00	
3/8 Inches	9.50 mm		-	-	100.00	
1/4 Inches	6.70 mm		-	-	100.00	
3/16 Inches	4.75 mm		-	-	100.00	
7 No	2.36 mm	1.06	0.53	0.53	99.47	
14 No	1.18 mm	7.34	3.67	4.20	95.80	
25 No	0.60 mm	22.36	11.18	15.38	84.62	
36 No	0.43 mm	13.90	6.95	22.33	77.67	
52 No	0.30 mm	18.41	9.21	31.54	68.47	
100 No	0.15 mm	28.77	14.39	45.92	54.08	
200 No	0.075 mm	11.81	5.91	51.83	48.18	
Base	Base					

2.01g/cm^3. The optimum moisture content (OMC) has its mean value as 8.88%. According to O'Flaherty (1988) the range of values that may be anticipated when using the standard proctor test methods are: for clay, maximum dry density (MDD) may fall before 1.44 mg/m^3 and 1.685 mg/m^3 and optimum moisture content (OMC) may fall between 20-30%, for silty-clay MDD is usually between 1.6 mg/m^3 and 1.845 mg/m^3 and OMC ranged between 15-25% and for sandy clay, MDD usually ranged between 1.76 mg/m^3 and 2.165 mg/m^3 and OMC between 8 and 15%. Thus, looking at the results of the soil samples, it could be noticed that they are sandy-clay. The low values of the dry density indicate that the natural deposits are loose and accounts for the high void ratio. The high void ratio of the soils increases with depth and lead to high infiltration rates. This high void ratio of the underlying strata would obviously give rise to high flow velocities, high seepage pressure and high internal erosion potential. The attributes favour the conclusion of Nwankwo et al., (1998) in the development of hydraulic gradient that caused the flow of water through soil strata with large seepage

Table 3. Atterberg Limit Result of the Studied Soil.

PROJECT/LOCATION: AMUZUKWU LATERITIC SITE							
Sample Ref:						**Classification: A - 7**	
		LIQUID LIMIT				**PLASTIC LIMIT**	
No. of Blows(Liquid Limit Test)		14	24	29	39	PL	PL
Container No.		13	2	21	6	5	26
Mass of wet soil + container	**W2**	67.95	70.34	72.77	75.28	56.02	58.75
Mass of dry soil + container	**W3**	56.52	58.45	60.17	62.34	50.97	53.10
Mass of container	**W1**	35.98	36.39	36.08	36.52	36.14	36.39
Mass of moisture	**W2 - W3 (a)**	11.43	11.89	12.60	12.94	5.05	5.65
Mass of dry soil	**W3 - W1 (b)**	20.54	22.06	24.09	25.82	14.83	16.71
Moisture Content (%)	**a x 100/b**	55.65	53.90	52.30	50.12	34.05	33.81

LIQUID LIMIT %	**DESCRIPTION**
52	
PLASTIC LIMIT %	
34	
PLASTICITY INDEX %	
18	**HIGHLY PLASTIC**

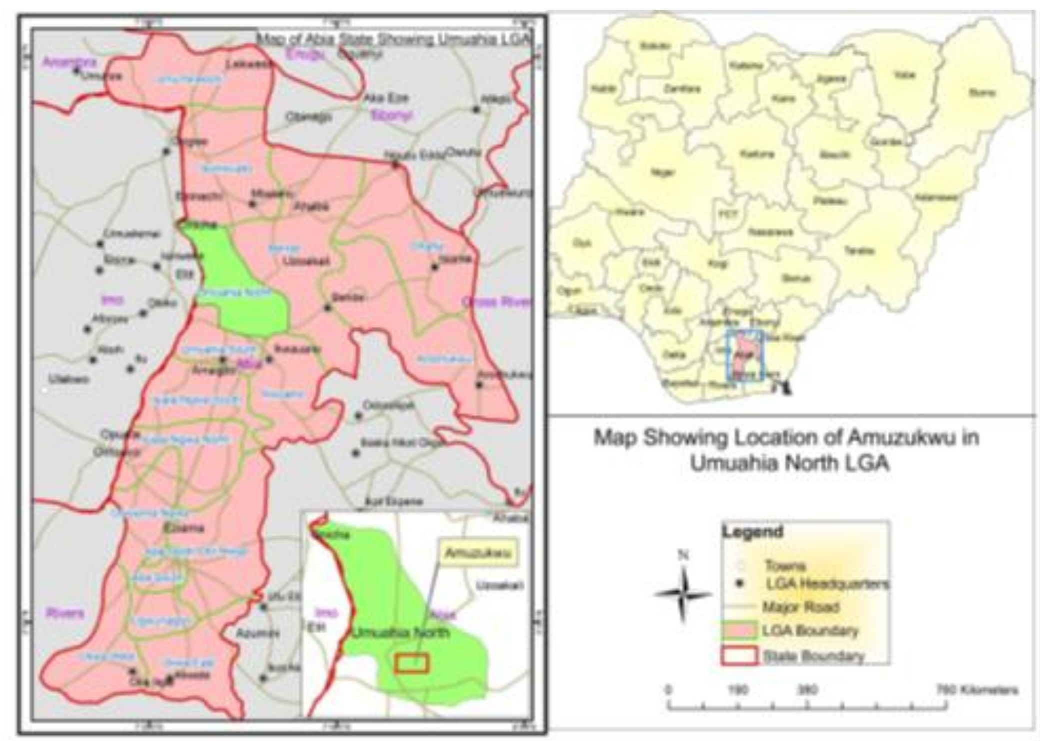

Figure 1. Map of Amuzukwu and its neighbouring communities.

velocity. This implies that the soil is not only susceptible to easy dispersal by flood waters but are also subjected to tremendous buoying (Okagbue and Ezechi, 1988). Table 5 shows the CBR test

Table 4. Compaction Test Result of the Studied Soil.

PROJECT/LOCATION: AMUZUKWU LATERITIC SITE								
DESCRIPTION: LATERITE								
VOLUME OF MOULD:	**924.00 cm3**							
Water Content	**2%**	**4%**	**6%**	**8%**				
Wt of Mould + Wet Soil (a)	3,650	3,780	3,950	3,850				
Wt of Mould .... (b)	1,980	1,980	1,980	1,980				
Wt of Wet Soil ..... (a - b)	1,670	1,800	1,970	1,870				
Bulk Density gm/cm^3	1.81	1.95	2.13	2.02				
Water Content %	**2%**		**4%**		**6%**		**8%**	
Container No.	5	7	15	24	34	13	15	33
Wt of Wet Soil + Container	74.29	76.79	78.23	79.79	82.33	84.26	90.74	93.02
Wt of Dry Soil + Container	72.75	74.92	75.80	77.22	78.59	80.33	85.62	87.77
Wt of Container Empty	36.99	35.99	36.32	36.42	36.33	36.27	36.39	36.15
Wt of Moisture	1.54	1.87	2.43	2.57	3.74	3.93	5.12	5.25
Wt of Dry Soil	35.76	38.93	39.48	40.80	42.26	44.06	49.23	51.62
Moisture Content	4.31	4.80	6.16	6.30	8.85	8.92	10.40	10.17
Average Moisture Content	4.55		6.23		8.88		10.29	
Dry Density gm/cm^3	1.73		1.83		2.01		1.84	
Water Content %	**2%**		**4%**		**6%**		**8%**	
CBR %			%		8.00%		%	
Weight of Sample = 3000g **O.M.C = 8.88%** **M.D.D = 2.01 g/cm^3** **CBR @ O.M.C = 8%**								

Table 5. CBR Test Result of the Studied Soil.

% WATER CONTENT:			**6%**	
	BASE		**TOP**	
PEN. MM	**DIAL**	**LOAD**	**DIAL**	**LOAD**
0.625	0.421	42.1	0.367	36.7
1.250	0.547	54.7	0.547	54.7
1.875	0.895	89.5	0.852	85.2
2.500	1.089	108.9	1.044	104.4
3.750	1.620	162.0	1.551	155.1
5.000	1.671	167.1	1.632	163.2
6.250	1.887	188.7	1.954	195.4
CBR CALCULATION:				
CBR @ 2.5mm = Load/13.6				
CBR @5.0mm = Load/20.4				
CORRECTED LOAD KG				
PEN. MM	**BASE**		**TOP**	
2.500	108.85		104.40	
5.000	167.10		163.20	
CORRECTED CBR %				
2.500	8.00		7.68	
5.000	8.19		8.00	
	8.19		**8.00**	
	CBR:		**8%**	

result of the studied soil. According to clause 6201 of Federal Ministry of Works and Housing (FMWH, 1997) Specification Requirement, the minimum strength of base course material shall not be less than 80% C.B.R (unsoaked) while minimum strength for subgrade/fill shall not be less than 10% after at least 48 hours soaking. Thus, this soil has a CBR value of 8% and this proves its unsuitability for use as a subgrade material.

CONCLUSION AND RECOMMENDATION

Utilization of Amuzukwu-Ibeku Lateritic soil for engineering constructions especially in Umuahia town, without improving its properties or stabilizing this soil has led to failure of these constructions over time. For instance, the Amuzukwu-Ibom road which is well-known for its cracks and pavement failure is as a result of the usage of the soil in question as subgrade, whereas it doesn’t satisfy the specifications for lateritic soils used as subgrade. Thus, proper stabilization of this soil should be done before implied in construction works to avoid future failures or loss. Thus, it is recommended that laboratory tests be carried out on borrow pit materials to be used for construction of roads so as to know their suitability for the intending purposes which would or could reduce cost of maintaining such roads in the long run if proper materials are selected or used, that could make roads stand a test of time. Also, resident engineers and contractors should always work in strict adherence to code of ethics of engineering profession so as to achieve or maintain best practices.

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